International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 737-744

IMPROVEMENTS IN SURFACE FINISH OF INCONEL 625 FLAT SURFACES USING MULTI-POLE MAGNETIC TOOL

HARISH KUMAR, GURPREET SINGH & ARUN KUMAR

Department of Mechanical Engineering, Chandigarh University, Gharuan, Mohali, Punjab, India

ABSTRACT

With technological developments, new metals and alloys are being developed to meet the industrial demands. Inconel 625 is one such nickel based alloy, which has excellent materialistic properties. Due to its superior properties, it has become the choice of nuclear industries, marine applications, solar power stations, heat exchanger tubing etc. But, machining and finishing of this alloy is difficult task with conventional methods. In present research work, Magnetic abrasive finishing has been implemented to improve the surface finish of flat Inconel 625 surfaces. The main parameters considered in present work are: processing time, weight %age of abrasive and pole rotational speed. Effect of process parameters on the percentage improvement in surface finish (PISF) has been analyzed. For experimentation design, Response Surface Methodology is used and experimental results have been analyzed using ANOVA. The results indicate that Magnetic abrasive finishing can be successfully implemented to finish the flat Inconel 625 work piece and parameters like processing time, pole rotational speed and Wt. % of abrasives have significant effect on PISF.

KEYWORDS: Inconel 625, MAF, PISF & Ferro-Magnetic Abrasive Particles

Received: Mar 21, 2019; **Accepted:** Apr 11, 2019; **Published:** May 10, 2019; **Paper Id.:** IJMPERDJUN201982

Original Article

INTRODUCTION

Inconel 625 is a nickel based super alloy, which was developed in the 1960s to meet the new industrial requirements. Due to its materialistic properties like high tensile strength at intermediate temperature, resistance against corrosion and oxidation, high fatigue and creep strength, it became the choice of nuclear industries, marine applications, solar power stations, heat exchanger tubing etc. However, due to the presence of hard alloying elements in the microstructure of Inconel 625, it is very hard to machine/finish with conventional machining/finishing methods. Various researchers had made many efforts to machine and finish the Inconel 625 surfaces with conventional techniques. Ultrasonically assisted turning (UAT) was employed to test the machinability of Inconel 625 (Maurotto, 2012). A coated tool was also tried during turning of the Inconel 625 to explore the optimal parameters (Marimuthu and Baskaran, 2014). Nath et al. examined the process optimization of alloys for the face milling with index able copy face mill inserts (Nath, 2015). Moreover, the tool flank wear conditions were also examined utilizing PVD-TiAlN coated carbide and ceramic tool during the machining of Inconel 625 alloy (Jahanbakhsh, 2016), (Lofti, 2016). It was observed that poor surface finish, tool wear and high cutting forces are major issues during conventional machining of Inconel 625. To overcome these machining issues, various researchers tried nontraditional machining methods such as EDM, WEDM, Laser machining and ultrasonic machining. Inconel 718 and Inconel 625 machined on EDM and effect of parameters like peak current, pulse on time and pulse off time on surface roughness and MRR has been analyzed (Dhanabalan, 2014). Further, the powder mixed EDM process was also implemented on Inconel 625, to get better the surface finish and MRR as

compared to simple EDM. Inconel 625 also machined with WEDM to explore effect of various machining parameters on MRR and Surface finish [Goyal, 2017]. Moreover, electrochemical drilling was also utilized for performance optimization of Inconel 625 [8]. Surface finish of Inconel 625 can also be improved with another advanced process known as Magnetic Abrasive finishing (MAF). In MAF, work piece is held between North Pole & South Pole of magnets. The gap between the work piece and magnet is filled with mixture of Ferro magnetic particles and abrasive particles. These particles are attracted towards the magnet poles when magnetic field has been established, As a result of this, A flexible magnetic abrasive brush is generated which is used to finish the work piece surface.

The various authors have successfully implemented this process on different materials(Kumar, 2013). The magnetic abrasive finishing utilized for internal finishing of SUS 304 stainless steel using mixed type magnetic abrasive. It has been observed that surface roughness decreased from 0.7µm to 0.2µm (Shinmura, 1995). The MAF using pole rotation system also utilized to deliver excellent finish of internal surface of work piece (Yamaguchi, 2000). Further, the internal surface finish of 0.02µm of alumina ceramics parts is obtained using MAF with a blend of ordinary abrasives and ferrous particles (Yamaguchi, 2004). MAF also performed on stainless steel (AISI316) to explore the impact of parameters like magnetic flux density and working gap utilizing L9 orthogonal array. It has been observed that both the working gap and magnetic flux density highly affect change of surface finishing (Ki and Kwak, 2010). Further, Ultrasonic assisted magnetic abrasive finishing incorporates the utilization of ultrasonic vibrations and MAF procedures to finish surfaces (Mulik and Pandey, 2010). The researchers also implemented simultaneous internal and external surface finishing of the stainless steel needles needle. Both the internal & external surfaces of needles simultaneously finished to around 0.01 µm (Nteziyaremyea, 2014). Moreover, double disk MAF process was also implemented on flat work surface to understand the effect of process factors namely upper and lower working gap rotational speed, abrasive weight percentage on the normal finishing force and finishing torque. The analysis of the experimental data showed that normal finishing forces is affected most significantly by lower and upper working gap, and finishing torque is effected mostly by the lower working gap and rotational speed of the magnetic disk (Sihag, 2014). Magnetic abrasive finishing has been also implemented for successful finishing of Inconel718 flat surfaces (Choudhary, 2017), (Singh, 2017). In another research work, a multi-point magnetic tool has been implemented to investigate the effects of process parameters on material removal of Inconel625 (Singh, 2018). In present research work, effect of three process parameters (Processing time, pole rotational speed and weight percentage of abrasives) on percentage improvement in surface finish of Inconel625 has been analyzed.

EXPERIMENTAL SETUP

An experimental setup has been developed to analyze the effects on surface finish of Inconel625 flat surfaces with multi-pole magnetic tool. An aluminum rod (Ø37 mmx16.5 mm) is used to develop the multiple pole magnetic tool. Three Nd-Fe-B magnets of (Ø20 mm x 20 mm) are inserted inside the aluminum rod (Figure 1). Then, this multi-pole magnetic tool is held in the spindle of vertical milling machine to finish Inconel 625 flat surface (50 mm x 50 mm x 5 mm). The left or right and up or down movement of milling machine bed is controlled by screw mounted on the machine. The working gap between work piece and tool is maintained by adjusting the screw available on the vertical milling machine as represented in figure 2.

Vertical milling machine spindle speed ranges from 80 to 520 rpm. A suitable fixture is mounted on the bed and workpiece is held in the fixture. Moreover, another Nd-Fe-B magnet (Ø20 x10 mm) is placed below the specimen, in order

to increase the magnetic flux density.

Figure 1: Bottom View of Tool

Figure 2: Experimental Setup

FINAL EXPERIMENTATION

In the present experimentation work, three process parameters (processing time, pole rotational speed and weight percentage of abrasive particles) has been selected as input process parameters. Flat square Inconel 625 (50 mm x 50 mm x 5 mm) specimen has been selected as workpiece. The experimental conditions are shown in the table 1.

Table 1: Experimental Conditions

Work piece material	Inconel 625 (50 mm x 50 mm x 5 mm)
Magnetic Tool	Three Nd-Fe-B Magnet (Ø10 x 20 mm)
Supporting Magnet	Nd-Fe-B Magnet (Ø20 x 10 mm)
Ferro-Magnetic Abrasive Particles	Electrolytic iron particles (Ø300 µm) Silicon Carbide (Ø40 µm)
Quantity of abrasives	3 grams.
Working gap	2 mm

In present experimental work, the flat Inconel 625 workpiece has been held in the fixture, which was mounted on the bed of milling machine. The magnetic tool was held inside spindle of vertical milling machine and another magnet was also placed below bottom surface of workpiece. Hence, the mixture of ferro-magnetic iron particles (Ø300 µm) and Silicon carbide abrasive particles (Ø40 µm) with selected quantity was supplied in the gap (2 mm) between magnetic tool and workpiece. A barrel finishing (soluble type) compound (1.5 ml) has been used for each experiment. A flexible magnetic brush was generated at poles due to strong magnetic field, which acts as finishing tool. The process parameters and range were selected on the basis of pilot experimentation and literature review studies. The selected parameters have been given in the table 2.

Table 2: Process Parameters with Selected Range

Parameters	Symbol	Level		
		-1	0	1
Processing Time (mins.)	A	30	60	90
Pole Rotational Speed (R.P.M.)	B	120	220	320
Weight %age of abrasive (%)	C	25	35	45

For experimentation design, Response Surface Methodology was used. Total seventeen experiments have been conducted randomly with the selected process parameters as per plan. After experimentation, surface roughness was

measured with telesurf roughness tester and percentage improvement in surface finish was calculated. In this experimental work, the surface finish improved from 1.87 -3.79 µm to 0.31-1.70 µm using multi pole magnetic tool. The results have been shown in Table 3. An ANOVA has been utilized to examine the results.

Table 3: Experimental Plan and Output Response

Std.	Run	Processing Time (min)	Pole Rotational Speed (RPM)	Wt. %age of Abrasive	PISF (%)
11	1	0	-1	1	54
14	2	0	0	0	74
17	3	0	0	0	78
16	4	0	0	0	71
2	5	1	-1	0	87
10	6	0	1	-1	77
9	7	0	-1	-1	71
12	8	0	1	1	69
5	9	-1	0	-1	61
8	10	1	0	1	66
7	11	-1	0	1	55
13	12	0	0	0	76
6	13	1	0	-1	78
3	14	-1	1	0	74
1	15	-1	-1	0	22

RESULTS AND DISCUSSIONS

After conducting all the experiments, percentage improvement in surface finish is calculated and analyzed using design expert software. Three selected parameters are analyzed and discussed below as follows:-

EFFECT OF PROCESSING TIME AND POLE ROTATIONAL SPEED

The combined effect of processing time and pole rotational speed is represented in Figure 3. It is clearly observed from graph that PISF varies directly when we considered two input factor up to some extent i.e. processing time and pole rotational speed. PISF increase with increase in processing time and pole rotational speed, and then further decreases by increasing pole rotational speed. It maybe due to the reason that at higher pole rotational speed, there will be more surface abrasion rather than finishing. PISF is maximum when processing time is maximum and pole rotational speed is near to average value.

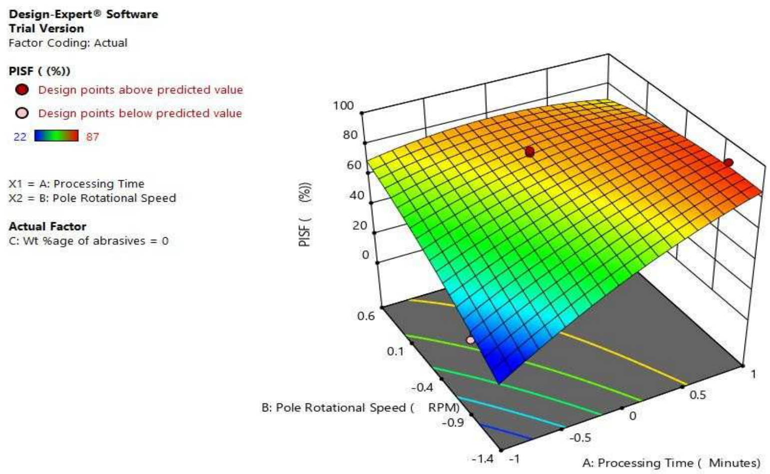

Figure 3: Combined Effect of Processing Time and Pole Rotational Speed on PISF

EFFECT OF PROCESSING TIME AND POLE ROTATIONAL SPEED

The combined effect of pole rotational speed and wt. % of abrasive is shown figure 4. It is observed from the graph that PISF initially starts increasing with the increase in values of both the selected parameters. PISF is maximum when pole rotational speed is maximum but weight percentage is minimum. On further increase in Wt %age of abrasive, PISF slightly start decreasing. It may be due to the reason that at higher weight percentage of abrasives, there will be more surface abrasion than finishing.

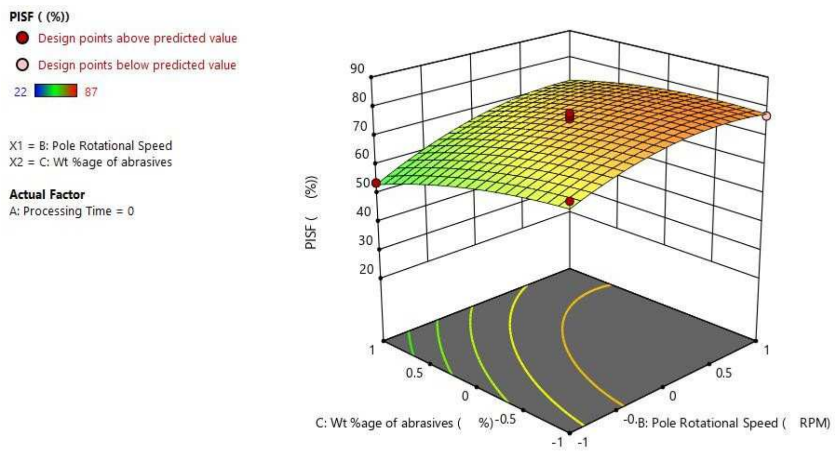

Figure 4: Combined Effect of Pole Rotational Speed and Wt. %age of Abrasive

EFFECTS OF PROCESSING TIME AND WT. %AGE OF ABRASIVE:

The combined effect of processing time and wt. % of abrasive is shown Figure 5. It is observed from the Figure 5 that PISF start increasing by increasing the processing time and wt. %age of abrasives. From Figure 5, it is clear that processing time is the most influencing factor, which is affecting the PISF. Maximum value of PISF is obtained at maximum value of processing time i.e. 90 minutes and minimum value of weight %age of abrasive i.e. 25%. It can be observed that processing the work surface with Ferro-magnetic particles containing 25% of abrasive particles, a strong flexible magnetic abrasive brush is formed. This brush easily removes most of surface irregularities by abrading maximum peaks on work surface when processing for 90 minutes. All tool marks have been removed and finished surface with very small surface roughness can be achieved.

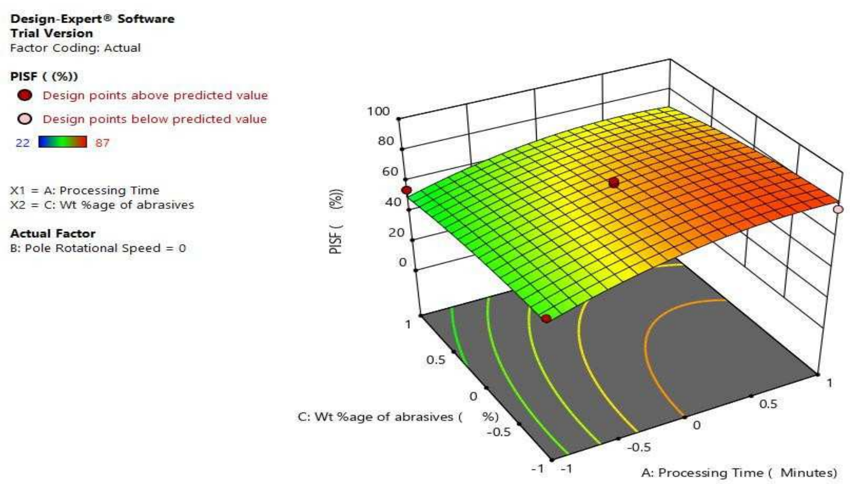

Figure 5: Combined Effect of Processing Time and Wt. %age of Abrasive

ANALYSIS USING SCANNED ELECTRONIC MICROSCOPY (SEM)

Scanning Electronic Microscopy is used to analyze the microstructure of work piece, before and after machining. Figure 6 shows scanned image of work piece before machining of Inconel 625. It shows us that there are some cuts and burrs present on the surface. These cuts may be present due to action of high cutting force and feed rate. The bubbles are present of surface due to thermal stress, which is induced during the grinding of work piece. Initial microscopy image is used for comparison with finished image of work piece.

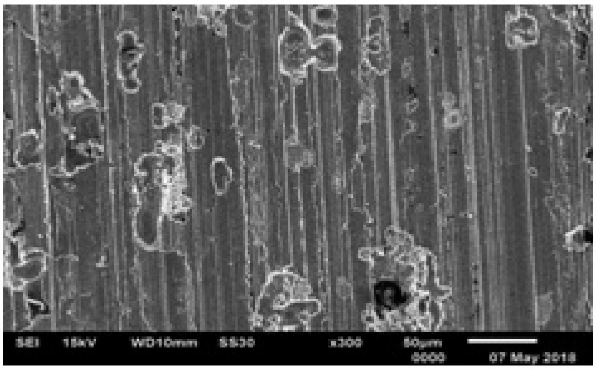

Figure 6: SEM of Initial Surface

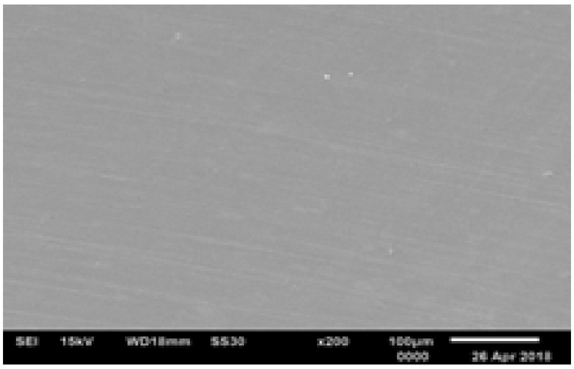

Figure 7: SEM at Processing Conditions (Time 90 min, Speed 120 RPM, Wt. % of Abrasives 35 %)

Figure 7 shows scanned electron microscopy image of finished work piece. The effect of selected parameters for this experiment is clearly visible when we compare Figure 6 and Figure 7 that, high amount of surface finish is obtained during this experiment because of high processing time and moderate weight %age of abrasive particles. Low pole rotational speed makes better contact of abrasive particles with surface of work piece under the provided amount of magnetic field.

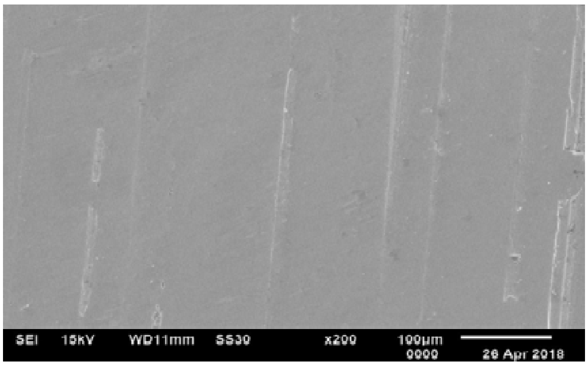

Figure 8: SEM at Processing Conditions (Time 60 min. Speed 320 RPM, Wt. % of Abrasives 25 %)

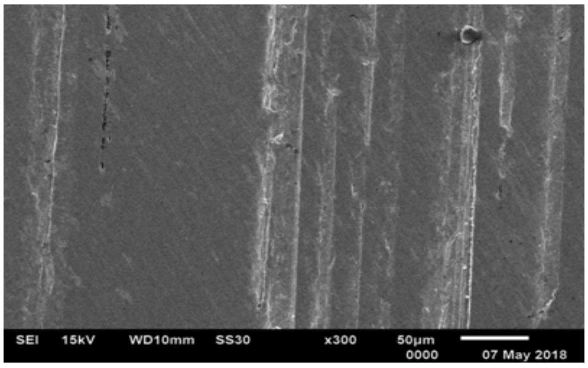

Figure 9: SEM at Processing Conditions (Time 30 min, Speed 220 RPM, Wt. % of Abrasives 45 %)

Figure 8 shows scanned electron microscopy image of finished work piece having process parameters processing time 60 minutes, pole rotational speed 320 RPM, wt. %age of abrasive is 25%. We see huge improvement in the surface finish of machined work piece with the initial work piece. The effect of high pole rotational speed strongly affects the surface finish, but it is observed that effect of pole rotational speed is slightly less than the processing time

Figure 9 shows scanned electron microscopy image of finished work piece having process parameters processing time 30 minutes, pole rotational speed 220 RPM, wt. %age of abrasive is 45%. Microscopic image shows improvement in

surface finish than the initial unprocessed work piece. The surface finish comes to be less than other two cases, when we have high processing time and high pole rotational speed. So, it is analyzed that the effect of wt. %age of abrasive depends upon the other two factors.

CONCLUSIONS

From this research work, following conclusions have been drawn.

- Magnetic Abrasive finishing has been successfully implemented to finish the flat Inconel 625 workpiece.
- Experimental result indicates that the parameters like processing time, pole rotational speed and Wt. % of abrasives shows significant effect on PISF.
- Processing time is most significant factor for PISF. Maximum PISF is achieved with maximum processing time of 90 minutes.
- Pole rotational speed is a parameter, which depends upon the other two parameters (processing time and Wt. % of abrasives). Best results are observed at intermediate values of pole rotational speed depending on other two parameters.
- Wt. % of abrasives provides best results while used at intermediate value (35%). With large value of Wt. %age of abrasive particles, there is more abrasion on the workpiece surface, which again starts increasing surface roughness.
- Best value of PISF is obtained when processing at 90 min. processing time, 120 rpm and 35 % of abrasives.

REFERENCES

1. *Maurotto A, Muhammad R, Roy A, Babitsky V.I, Silberschmidt V.V. 2012, Comparing machinability of Ti-15-3-3-3 and Ni-625 alloys in UAT, Procedia CIRP 1330 – 335.*
2. *Marimuthu P. and Baskaran R. 2014, Optimal setting of machining parameters for turning Inconel 625 using coated tool, Applied Mechanics and Materials Vol. 573 (pp. 632- 637).*
3. *Nath Chandra, Brooks Zachary, Kurfess T.R. 2015, Machinability study and process optimization in face milling of some super alloy with indexable copy face mill inserts, Journal of Manufacturing Processes 2088–97.*
4. *Lopez, J., Aguirre-Contreras, W. R., Gómez, M. E., & ZAMBRANO, G. (2017). Zn concentration influence on the structure, morphology and magnetic properties of Co (1-X) ZnxFe2O4 nanoparticles in ferrofluids. IASET, 6, 47-60.*
5. *Jahanbakhsh M, Farid A. Aand Lotfi M. 2016, Optimal flank wear in turning of Inconel 625 super alloy using ceramic tool, ProcIMechE Part B: J Engineering Manufacture, 1–9.*

   Lotfi M, Jahanbakhsh M, Farid A.A. 2016, Wear estimation of ceramic and coated carbide tools in turning of Inconel 625: 3D FE Analysis, S0301-679X (16)30002-0.
6. *Dhanabalan S, Sivakumar K and Narayanan C. Sathiya. 2014, Analysis of form tolerances in electrical discharge machining process for Inconel 718 and 625, Materials and Manufacturing Processes, 29:253–259.*
7. *Goyal Ashish. 2017, Investigation of material removal rate and surface roughness during wire electrical discharge machining (WEDM) machining of Inconel 625 super alloy by cryogenic treated tool electrode, S1018-3647(17)30333-6.*

8. *Mohamed, O. A., Masood, S. H., & Bhowmik, J. L. (2015). Optimization of fused deposition modeling process parameters: a review of current research and future prospects. Advances in Manufacturing, 3(1), 42-53.*

9. *Manikandan N, Kumanan S, Sathiyanarayanan C. 2016, Multiple performance optimization of electrochemical drilling of Inconel 625 using Taguchi based grey relational analysis, Engineering Science and Technology, an International Journal.*

10. *Kumar Harish, Singh Sehijpal, Kumar Pardeep. 2013, Magnetic Abrasive Finishing – A Review, International Journal of Engineering Research & Technology, 2 (3), (pp. 1-9)*

11. *Shinmura T, and YamaguchiH.1995, Study On A New Internal Finishing Process By The Application of Magnetic Abrasive Machining,(pp. 798-804).JSME International Journal, Series C, 38 (4).*

12. *Yamaguchi H and Shinmura T, 2000, Study of An Internal Magnetic Abrasive Finishing Using A Pole Rotation System, Journal of International Societies for Precision Engg. and Nano Technology, 24, pp237-244.*

13. *Ganesh, N., Kumar, M. U., Kumar, C. V., & Kumar, B. S. (2014). Optimization of cutting parameters in turning of EN 8 steel using response surface method and genetic algorithm. International Journal of Mechanical Engineering and Robotics Research, 3(2), 75.*

14. *Yamaguchi H and Shinmura T. 2004, Internal Finishing Process for Alumina Ceramic Components by a Magnetic Field Assisted Finishing Process, (pp.135–142). Precision Engineering, 28.*

15. *Ki T. W, Kwak J. S. 2010, A study on deburring of magnesium alloy plate by magnetic abrasive polishing,(pp. 189– 194). International Precision Engineering Manufacturing 11(2).*

16. *Mulik R. S. and Pandey P.M. 2010, Mechanism of Surface Finishing in Ultrasonic- Assisted Magnetic Abrasive Finishing Process, DOI: 10.1080/10426914.2010.499580.*

17. *Nteziyaremyea V, Wangb Y, Shihb A., Yamaguchi H. 2014, Surface Finishing of Needles for High-Performance Biopsy,(pp. 48 – 53). Procedia CIRP 14.*

18. *Sihag Nitesh, Kala Prateek, Panday Pulak M. 2015, Chemo Assisted Magnetic Abrasive Finishing: Experimental Investigation, (pp. 539–543).Procedia CIRP, 26.*

19. *Choudhary A, Kumar H. 2017, Studies in Surface Finishing of Inconel718 Flat Surface with Magnetic Abrasive Finishing, (pp. 139-150). International Journal of Mechanical and Production Engineering Research and Development, . 7(4).*

20. *Bazaria, B., & Kumar, P. (2018). Optimization of spray drying parameters for beetroot juice powder using response surface methodology (RSM). Journal of the Saudi society of agricultural sciences, 17(4), 408-415.*

21. *Singh Lovepreet, Kumar Harish, Kumar Arun, 2017, Parametric Study in Surface Finishing of Inconel718 Surface with Magnetic Abrasive Finishing Process,(pp 223-234). International Journal of Mechanical and Production Engineering Research and Development, 7(4).*

22. *Singh Amandeep, Kumar Harish, Singh Gurpreet, 2018, Investigations into Machining of Inconel 625 Flat Surfaces with Multi-pole Magnetic Tool, Indian Journal of Science and Technology, 11(28),DOI: 10.17485/ijst/2018/v11i28/130779.*